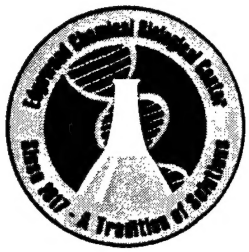

EDGEWOOD

CHEMICAL BIOLOGICAL CENTER

U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

ECBC-TN-017

CHARACTERISTICS, SAMPLING EFFICIENCIES, AND POSSIBLE IMPROVEMENTS TO THE AEROSOL TO LIQUID PARTICLE EXTRACTION SYSTEM (ALPES)

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January 2004

ABERDEEN PROVING GROUND, MD 21010-5424

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
XX-01-2004	Final	Sep 2003 - Oct 2003

4. TITLE AND SUBTITLE
Characteristics, Sampling Efficiencies, and Possible Improvements to the Aerosol to Liquid Particle Extraction System (ALPES)

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Kesavan, Jana; and Hottell, K. Aubrey*

5d. PROJECT NUMBER
622384/ACB2

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES)
DIR, ECBC, ATTN: AMSRD-ECB-RT-TA, APG, MD 21010-5424

8. PERFORMING ORGANIZATION REPORT NUMBER
ECBC-TN-017

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
* Student Contractor assigned to Research and Technology Directorate, U.S. Army Edgewood Chemical Biological Center (ECBC).

14. ABSTRACT
Sampler characteristics and sampling efficiency measurements of the Aerosol to Liquid Particle Extraction System (ALPES) were determined using monodisperse polystyrene latex (PSL) microspheres and fluorescent oleic acid droplets with fluorometer analysis. Sampling efficiency measurements of ALPES were determined using 0.5- and 1-μm PSL microspheres, and 5 μm sodium fluorescein tagged oleic acid (fluorescent oleic acid) particles. The results show that the ALPES has a peak efficiency of 57.4 ± 5.1% for 5-μm particles. Tests conducted to determine possible improvements to the sampler showed that slowing the air flow rate of the sampler significantly increased the sampling efficiency, and washing the inside of the outer cylinder increased the collection efficiency. Dry versus wet collection tests showed that there is no difference in collection efficiency for these conditions.

15. SUBJECT TERMS
Aerosol
Sampling efficiency
Samplers
ALPES

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Sandra J. Johnson
U	U	U	UL	13	19b. TELEPHONE NUMBER (include area code) (410) 436-2914

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PREFACE

The work described in this report was authorized under Project No. 622384/ACB2. This work was started in September 2003 and completed in October 2003.

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Acknowledgment

The authors acknowledge John Knapton for providing editorial assistance.

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CONTENTS

FIGURE

TABLE

CHARACTERISTICS, SAMPLING EFFICIENCIES, AND POSSIBLE IMPROVEMENTS TO THE AEROSOL TO LIQUID PARTICLE EXTRACTION SYSTEM (ALPES)

1. INTRODUCTION

This technical note is one in a continuing series of short reports intended to document and preserve the record of data from characterizing aerosol collectors. This report is not intended to be a comprehensive study or analysis. A technical note simply records a limited set of observations, offers some preliminary analysis, and if appropriate, provides a record of the measured data to the company that provided the device. Results of more thorough studies may be found in technical reports. In this study, the Aerosol to Liquid Particle Extraction System (ALPES), manufactured by Savannah River Technology Center, Aiken, SC, was tested in an environmentally controlled chamber at calm air conditions. Characteristics, sampling efficiencies, and possible improvements were evaluated using polystyrene latex (PSL) microspheres and fluorescent oleic acid droplets with fluorometer analysis. These tests were conducted to determine the sampling efficiency at calm air condition and do not include inlet efficiencies at varying wind velocities.

The sampling efficiency is defined as the efficiency with which an aerosol sampler collects the particles from the air. The total efficiency of an aerosol sampler is the product of the sampler's aspiration, transmission, and collection efficiencies. The aspiration efficiency of a sampler gives the efficiency with which particles enter into the sampler inlet. Transmission efficiency gives the efficiency with which the particles are transported to the collection point, and the collection efficiency gives the efficiency with which particles are captured and retained by the sampling medium. The sampling efficiency was determined by comparing the sample collected by the ALPES to reference samples collected by two stationary open face air filters. In addition, characteristics such as dimensions, air flow rate, and power consumption were measured. Possible improvements were investigated by washing components, collecting on dry surface, and slowing the air flow rate.

The sampler was only available for a 1-week period. Therefore, the number of tests and the number of particle sizes tested were limited. Some sampler characteristics were not measured due to the time limitation. Since only one sampler was available for testing, the variation in sampling efficiency between samplers was not determined.

2. EQUIPMENT AND FACILITIES

2.1 Chamber.

The tests were conducted in a 70 m^3 biosafety Level 1 chamber at the U.S. Army Edgewood Chemical Biological Center (ECBC). Chamber temperature and humidity can be set and maintained easily and accurately by a computer. Power receptacles inside the chamber are also controlled by this computer.

To achieve very low particle concentrations in the chamber, HEPA filters are installed at the air inlet to filter air entering the chamber. Similarly, HEPA filters are installed at the exhaust port to filter particles leaving the chamber. The aerosol concentration in the chamber is reduced by exhausting chamber air through the HEPA filters, and by pumping HEPA-filtered air into the chamber. The maximum amount of air flow that the exhaust pump can exhaust from the chamber is approximately 700 ft^3/min (approximately 2 x 10^4 L/min). There is also a small re-circulation system that removes air from the chamber, passes it through a HEPA filter, and delivers it back to the chamber. This system is useful when the aerosol concentration in the chamber needs to be reduced by a small amount.

Aerosols can be either generated outside and delivered to the chamber, or they can be generated inside the chamber. The chamber air is mixed by a fan before and/or during the experiment to achieve uniform aerosol concentration in the chamber. Previous tests showed that mixing the aerosol in the chamber for 1 min is adequate to achieve uniform aerosol concentration.

2.2 Aerosol to Liquid Particle Extraction System (ALPES).

A picture of the sampler is shown in the figure herein. This sampler uses the principle of charging the particles first and then collecting them using the opposite charged on the collection surface. In the first half of the tube, the particles are charged. In the second half of the tube, they are collected. In the particle charging region (ionization section), a positive high voltage wire runs in the center of the tube. In the collection region, a wetted negative high voltage collection surface is in the center to collect the particles. A water pump delivers the liquid to the top of the collection surface, and the liquid drains back to the bottom where it is pumped to the top again. This sampler is designed to have a flow rate of 250 L/min.

2.3 Sampler Characteristics Measurements.

The air flow rates for the reference filters were measured using a Buck Calibrator (A.P. Buck, Incorporated, Orlando, FL). The air flow rate of the ALPES was measured using a Kurz air flow meter (Kurz Instruments, Incorporated, Monterey, CA). The ALPES was designed to pull an air flow rate of 250 L/min. However, the measured flow rate was approximately 235 L/min at the inlet. The sampler is 22 in. tall, and the rectangular base (power supply) is 6 in. by 10 in. The sampler's power usage was 24.4 W as measured by a power meter (Extech Instruments, Waltham, MA).

3. TEST PROCEDURES AND ANALYSIS

3.1 Sampling Efficiencies and Possible Improvement Tests.

The first part of the test determined the sampling efficiency of ALPES. Tests were conducted with 0.5- and 1-μm PSL and 5 μm fluorescent oleic acid particles. Both methods are described below. The second part of the test investigated the possible improvements to the ALPES. First, the outer cylinder was washed to determine the amount

of particles deposited on the surfaces. Second, instead of a wet collection, dry collection was conducted followed by washing of the surface at the end of sampling. Third, the air flow of the sampler was decreased to 153 L/min, and the sampling efficiency was determined using the wet collection method.

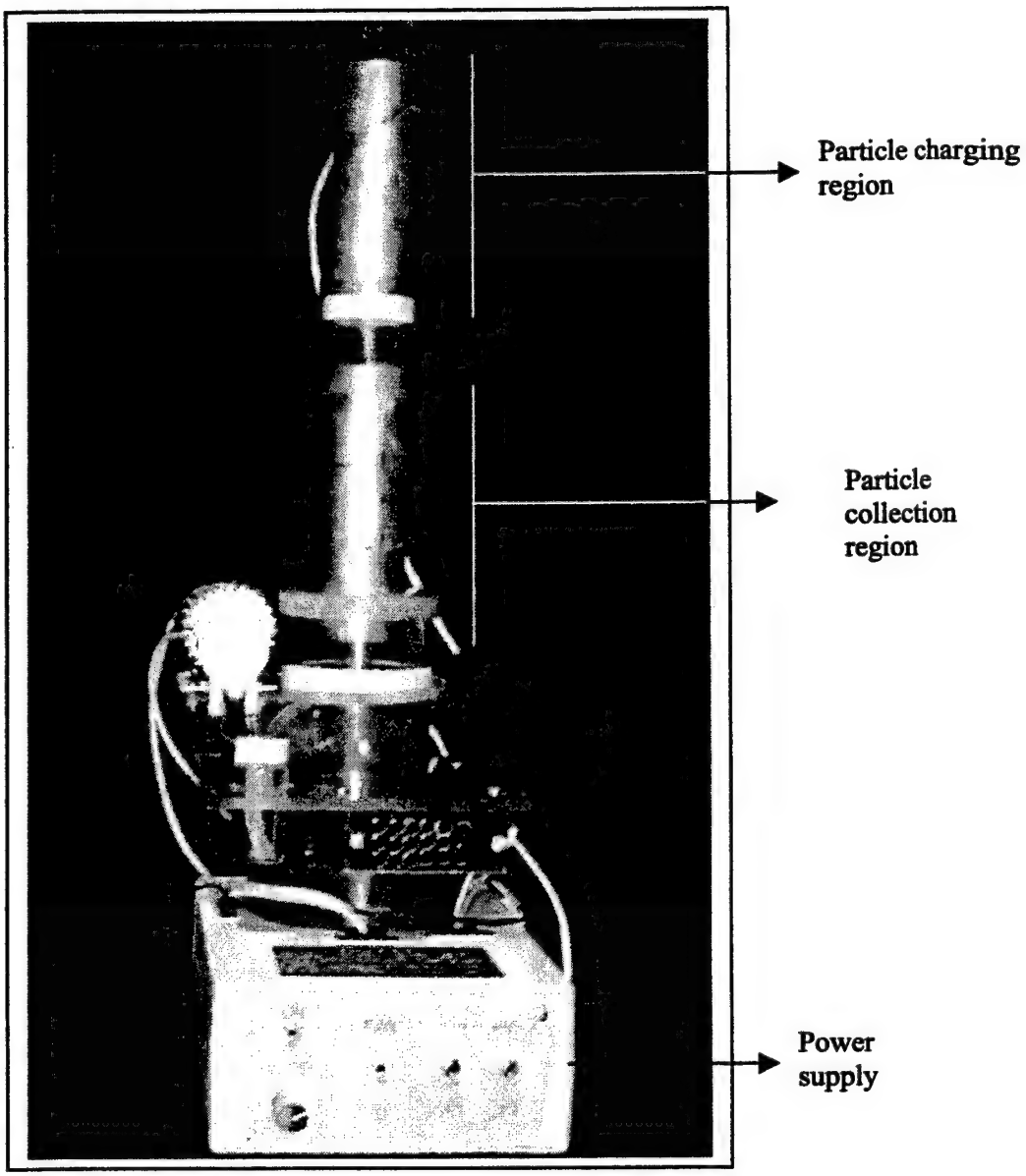

Figure. Aerosol to Liquid Particle Extraction System (ALPES).

3.2 PSL Microsphere Tests.

Sampling efficiency tests were conducted with 0.5 and 1 μm blue fluorescent PSL microspheres (Duke Scientific, Corporation, Palo Alto, CA). The microspheres were aerosolized using a 24 jet Collison nebulizer (BGI, Waltham, MA) and passed through a radioactive isotope

(Kr-85) neutralizer (TSI Incorporated, St. Paul, MN) to reduce the charge on the particles. During the experiment, the aerosol was generated for approximately 10 min and mixed for 1 min before sampling.

The samplers and the corresponding reference filters sampled the PSL aerosol simultaneously and for the same amount of time. Polycarbonate membrane filters (Osmonics Incorporated, Minnetonka, MN) were used as the reference filters to collect the fluorescent PSL microspheres. The sampler used deionized water with 0.01% Triton X-100 (Sigma Chemical Company, St. Louis, MO) for collecting PSL aerosols. After sampling, the sample liquid and filters were collected. The liquids were analyzed by the fluorometer directly; however, the membrane filters went through a particle removal procedure (Kesavan and Doherty 1999)[1] to remove microspheres from the filters into the liquid for fluorometer analysis. The removal procedure consists of placing the membrane filters into 20 mL of filtered, deionized water; then hand shaking for 10 s followed by vortexing for 50 s. The 60 s of hand shaking and vortexing were repeated four more times (total of 5 min) to completely remove fluorescent PSL microspheres from the membrane filters.

3.3 Sodium Fluorescein Tagged Oleic Acid Tests.

Sampling efficiency tests were conducted also with monodisperse fluorescent oleic acid particles. The monodisperse fluorescent oleic acid particles were generated using a Vibrating Orifice Aerosol Generator (VOAG, TSI Incorporated, St. Paul, MN). As with the PSL tests, the generated aerosol was passed through a Kr-85 radioactive isotope neutralizer to reduce the particle charge before delivering the aerosol to the chamber. The size of the generated particles was determined by sampling the aerosol onto a microscopic slide inserted into an impactor, and then measuring the droplet size using a microscope. The measured fluorescent oleic acid particle diameter was converted to an aerodynamic particle size using a spread factor (Olan-Figueroa et al. 1982)[2] and the density of fluorescent oleic acid. An APS was used to ensure that particle size did not change during the test. At the end of the aerosol generation, the aerosol in the chamber was mixed for 1 min before sampling. The concentrator and the corresponding reference filters sampled the aerosol for the same amount of time. Glass fiber filters (Pall Corporation, Ann Arbor, MI) were used as filter material to collect fluorescent oleic acid particles.

Glass fiber filters were removed from filter holders, put into a fluorescein recovery solution, and shaken on a table rotator (Lab-Line Instruments, Incorporated, Melrose Park, IL) for 1 hr. The recovery solution used in the tests consisted of water with a pH between 8 and 10, obtained by adding a small amount of NH_4OH (e.g., 1000 mL of water with 0.563 mL of 14.8 N NH_4OH). The wetability of the solution was increased using 0.01% Triton X-100. Factors that affect fluorescein analysis and the removal of fluorescein from filters are described in detail by Kesavan et al. (2001).[3] The fluorescence of the solution was measured using a fluorometer. All samples were analyzed either the same day of the experiment or the next day after the experiment.

3.4 Analysis.

Sampling efficiency was determined by comparing the amount of fluorescent material collected by the ALPES and the reference filters. The air flow rate of the sampler and the reference filters, and the liquid volume of the samples and reference solutions were considered in the calculation.

The sampling efficiency was calculated by the following equation:

$$\text{Sampling Efficiency} = \frac{\left[\frac{(\text{fluorometer reading of sample}) \times (\text{liquid volume})}{(\text{air flow rate})}\right]}{\text{Average of}\left[\frac{(\text{fluorometer reading of reference filter}) \times (\text{liquid volume})}{(\text{air flow rate})}\right]} \times 100 .$$

Prewashes were performed to confirm that the samplers were free of fluorescent material before each test. In general, there was a very small amount of fluorescence in the prewash solution, and corrections were not made for this small amount.

4. RESULTS

The sampler characteristics and sampling efficiency results of the ALPES are shown in the table herein. The ALPES is a small sampler with low power requirement (24.4 W). The results show that the highest sampling efficiency is 57.4 ± 5.1% for 5-μm particles.

Washing of the tube showed that the wash had an extra 14.9% of the sample deposited in the tube. Dry versus wet collection surface showed no difference in collection efficiency (wet: 39.6 ± 5.6%; dry: 37.3 ± 0.4%). There was a significantly higher sampling efficiency when the air flow rate was decreased to 153 L/min for 1-μm particles (39.6 + 5.6% for 235 L/min air flow versus 58.1 ± 3.2% for 153 L/min air flow).

5. DISCUSSION AND CONCLUSIONS

The sampling efficiency and the location of aerosol losses were determined in this study. Sampling efficiency measurements of the Aerosol to Liquid Particle Extraction System (ALPES) were determined using 0.5 and 1 μm polystyrene latex (PSL) microspheres, and 5 μm sodium fluorescein tagged oleic acid (fluorescent oleic acid) particles. The results showed that the ALPES has a peak efficiency of 57.4 ± 5.1% for 5-μm particles. Tests conducted to determine possible improvements showed that reducing the air flow rate of the sampler significantly increases the sampling efficiency. In addition, there is some deposition of particles on the inside of the outer cylinder that can be washed to increase the sample concentration. Dry versus wet collection tests showed that there is no difference in collection efficiency at these conditions.

This sampler was only available for testing for 1 week. Therefore, the number of particle sizes and the number of tests were limited. Some of the sampler characteristics were not measured due to time limitations. Because only one sampler was available for testing, these results do not show what variations might be expected between samplers of the same model.

Table. Sampler Characteristics and Efficiencies of ALPES.

Characteristics	ALPES	
	Condition One	Condition Two
Designed air flow rate (L/min)	250	
Air flow rate measured at inlet (L/min)	235	153
Electrical Properties, measured at ECBC Power, W Voltage, V Current, A	 24.4 118.5 0.39	 not measured
Weight (pound)	Not Measured	
Dimensions (inch) Inlet Cylinder Diameter Height Box Width Length	 Not Measured 22 6 10	 no change
Aerodynamic Particle Size (μm)	Sampling Efficiency (%) ± one standard deviation	
0.5 1 5	44.0 ± 8.0 39.6 ± 5.6 57.4 ± 5.1	58.1 ± 3.2

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